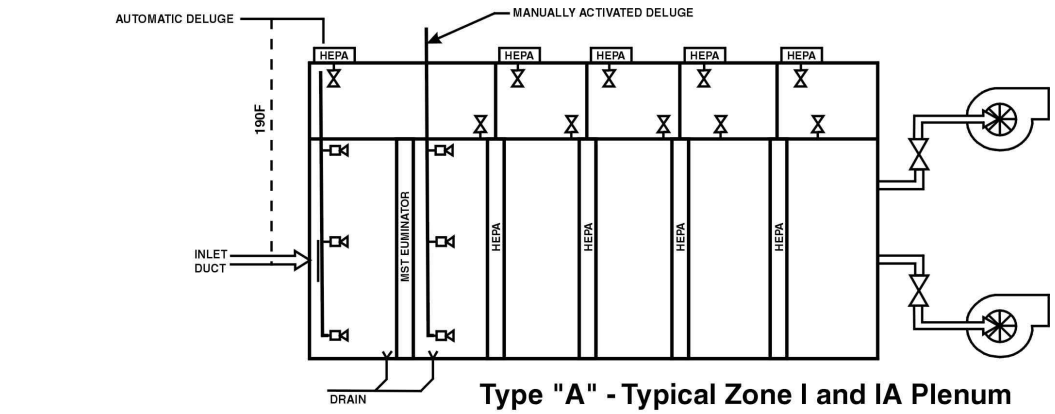
best arrangement for a 600-cfm system would be a 2-wide by 3-high array.

Where possible, banks should be laid out in an array of three filters high or nine Type II adsorber cells high. When floor space is at a premium, the bank may be arranged with one 3-high array above another, with a service gallery between, as shown in FIGURES 4.7 and 4.8. Thus, an 18,000-cfm bank might be arranged in an array 6-wide by 3-high or 3-wide by 6-high, with a service gallery between the third and fourth tiers. The arrangement of a 24,000-cfm bank in a 6-wide by 4-high array would be undesirable. A better arrangement is an array 8-wide by 3-high or, if floor space is at a premium, two 4-wide by 3-high arrays, one above the other, separated by a service gallery. In no case should filter changing require the use of ladders or temporary scaffolding. To require a workman dressed in bulky protective clothing (with sight obscured by a respirator or gas mask and sense of feel dulled by double gloves) to manipulate a ladder or scaffold within the confines of a filter house is an open invitation to filter damage and personnel injury. Based on the 95th-percentile man,[19] the maximum height at which a man can operate hand tools effectively is 78 in., and the maximum load he can handle at a height of 5 ft or more is 40 lb.[20] Therefore, provision for access to the higher tiers of filters is necessary. In fact, ASME AG-1, Subarticle HA-4433,[26] requires that a permanent platform be installed to access filters to access filters above 6 ft.

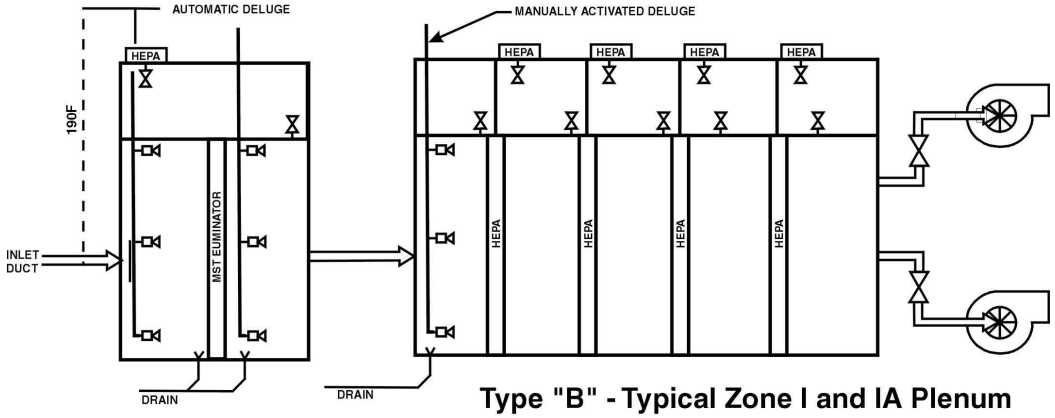
Filter banks should be rectangular. The use of odd-shaped banks to limit installed filter capacity to calculated system airflow requirements increases construction costs significantly. By filling out the rectangle, construction costs will be less. In addition, if all nine spaces are filled with filters, operating costs may also be reduced because the additional filters permit operation at a lower flow rate per unit resulting in longer filter life and reduced filter-change frequency, as discussed in Chapter 2. For the purposes of laying out adsorber banks, three Type II (tray) adsorbers will fit vertically into the space occupied by one 24- by 24-in. HEPA filter.

4.4.13 FLOOR PLAN OF FILTER BANKS

Vertical banks may be arranged in a plane (**FIGURES 4.28 through 4.35**). Judicious layout of a bank can often reduce pressure losses in the system and bring about more uniform dust-loading of filters, thereby equalizing utilization of the filters installed in the bank. If the open side of a U-arrangement is centered on the fan inlet, for example, the distances from the filters to the fan are more or less equalized and the bank may in effect form an inlet box that enhances fan-inlet conditions and produces more uniform pressure drop across, and loading of, the filters. On the other hand, straight (plane) banks are safer from the standpoint of fire-spread than U-shaped or stepped arrangements.[22]

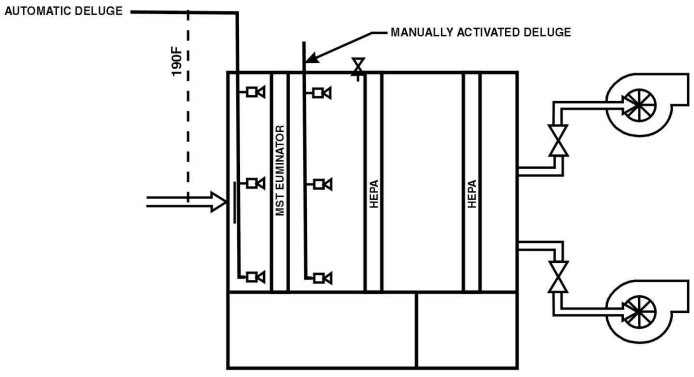


Type "A" - Typical Zone I and IA Plenum



Type "B" - Typical Zone I and IA Plenum

Heal Chamber



Type "C" - Typical Zone II and III Plenum

Figure 4.28

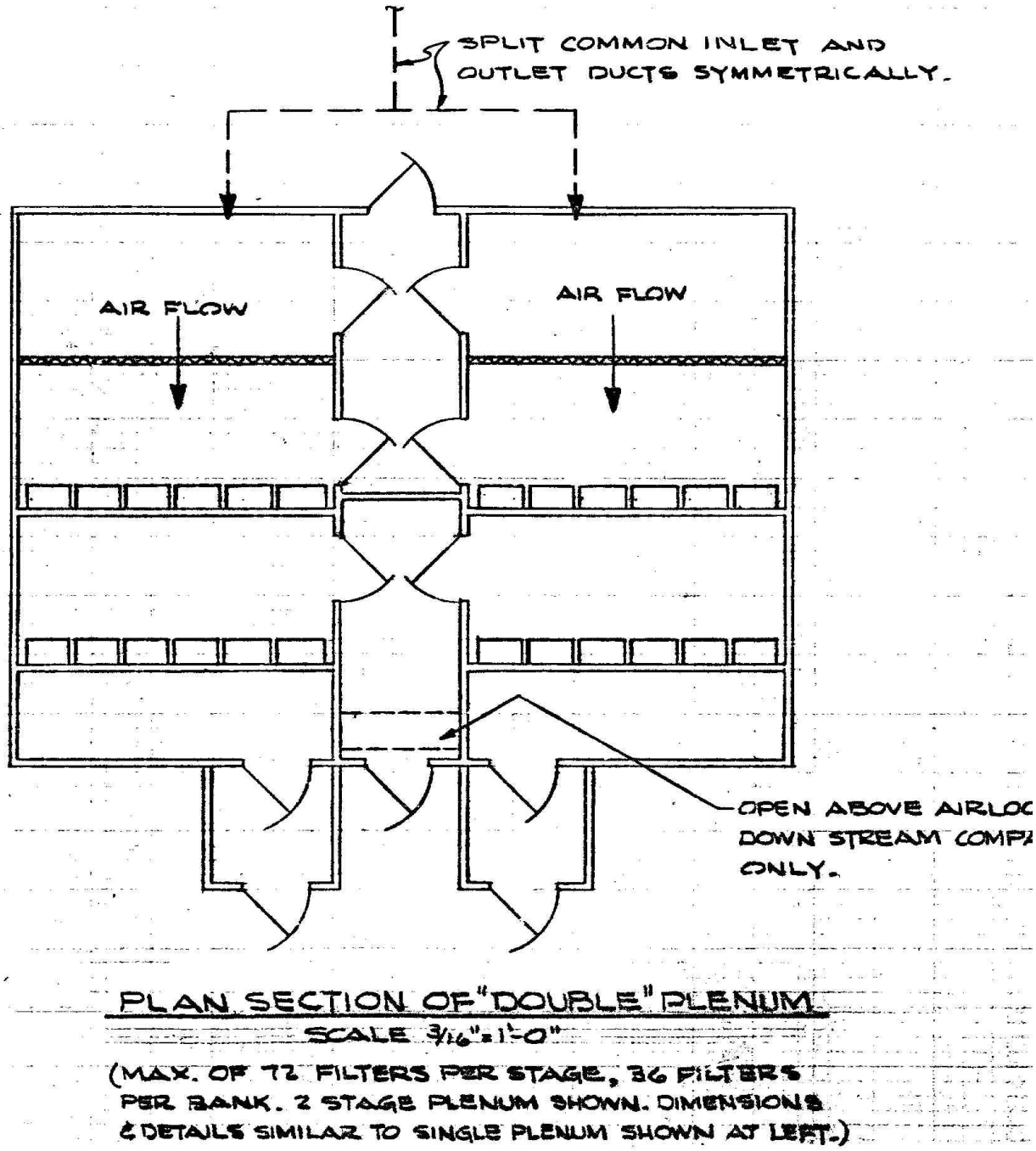

SPLIT COMMON INLET AND
OUTLET DUCTS SYMMETRICALLY.
AIR FLOW
AIR FLOW
OPEN ABOVE AIRLOC
DOWN STREAM COMP
ONLY.
PLAN SECTION OF "DOUBLE" PLENUM
SCALE 3/16"=1'-0"
(MAX. OF 72 FILTERS PER STAGE, 36 FILTERS
PER BANK. 2 STAGE PLENUM SHOWN. DIMENSIONS
& DETAILS SIMILAR TO SINGLE PLENUM SHOWN AT LEFT.)

Figure 4.29

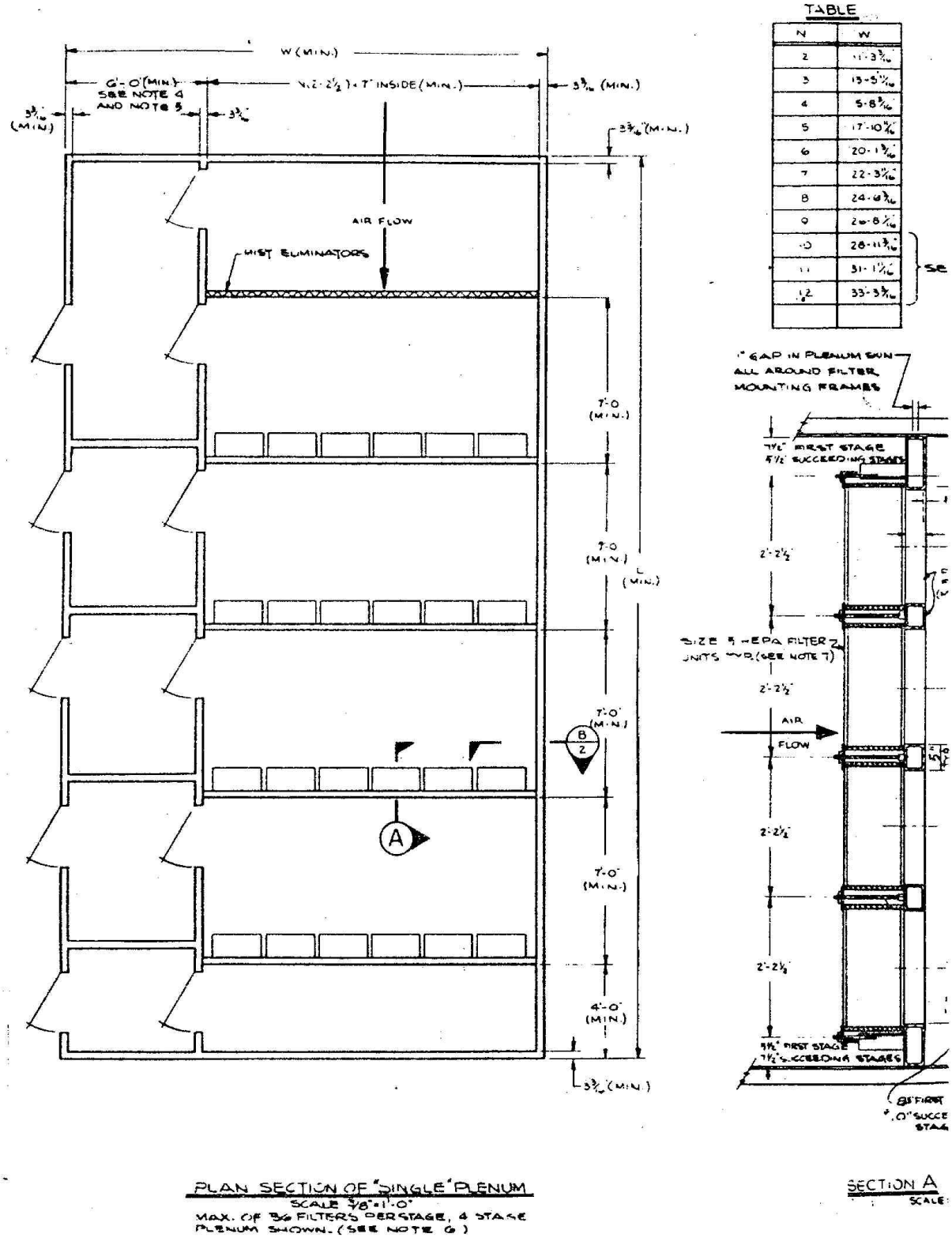
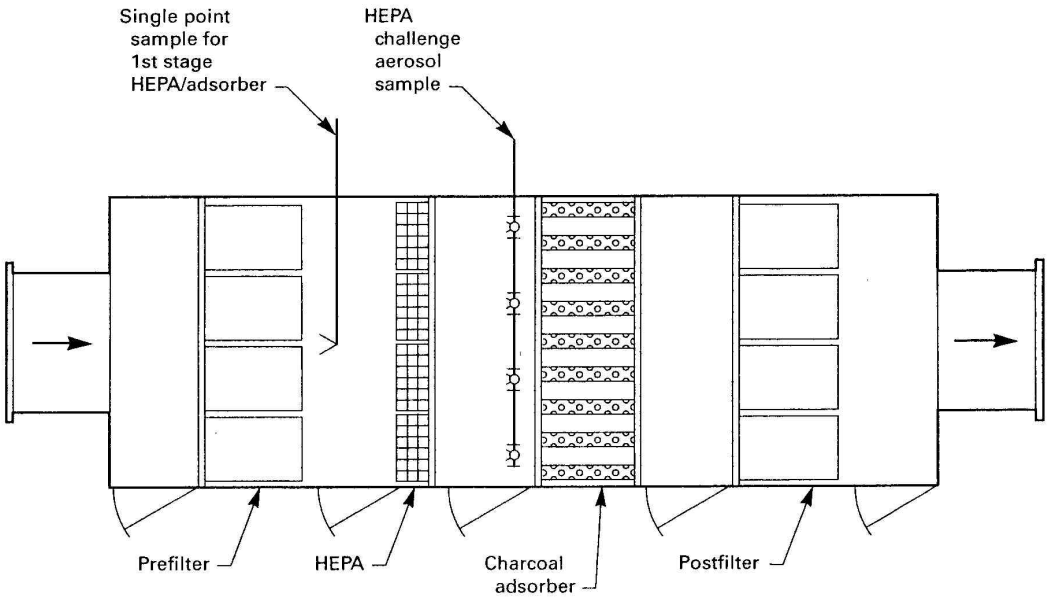


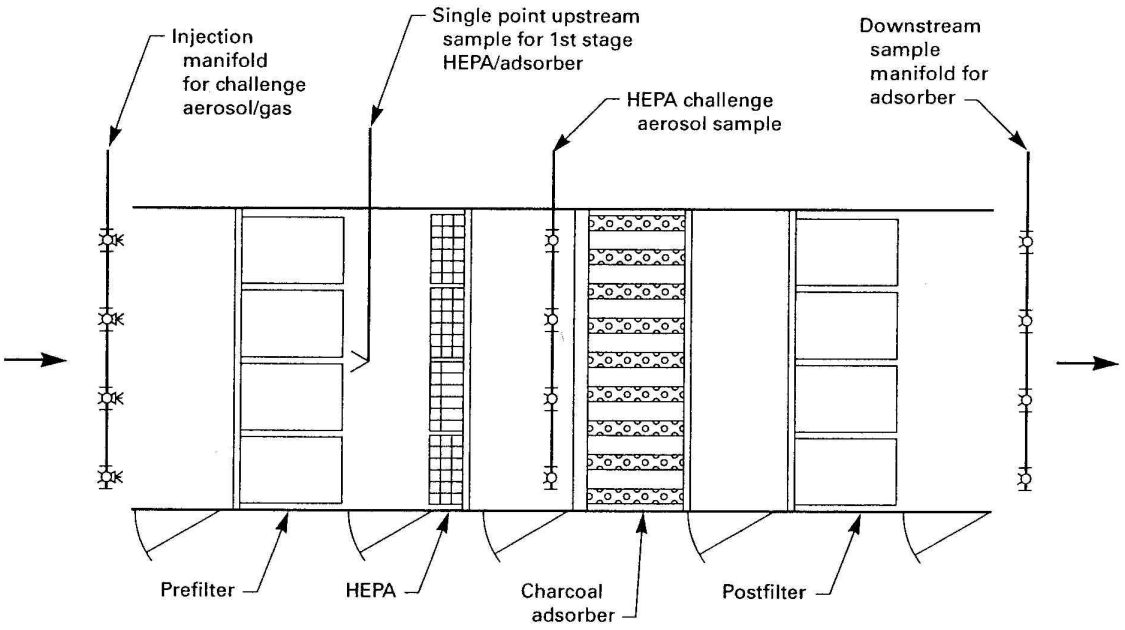
TABLE
N
W
W (MIN.)
6'-0" (MIN.) SEE NOTE 4 AND NOTE 5
N (2'-2½") + 7" INSIDE (MIN.)
3¾" (MIN.)
AIR FLOW
MIST ELIMINATORS
7'-0" (MIN.)
7'-0" (MIN.)
7'-0" (MIN.)
7'-0" (MIN.)
4'-0" (MIN.)
1" GAP IN PLENUM SUN ALL AROUND FILTER MOUNTING FRAMES
SIZE 5 HEPA FILTER UNITS WIDE (SEE NOTE 7)
AIR FLOW
2'-2½"
PLAN SECTION OF "SINGLE" PLENUM
SCALE ⅜"=1'-0"
MAX. OF 36 FILTERS PER STAGE, 4 STAGE PLENUM SHOWN. (SEE NOTE 6)
SECTION A

Figure 4.30



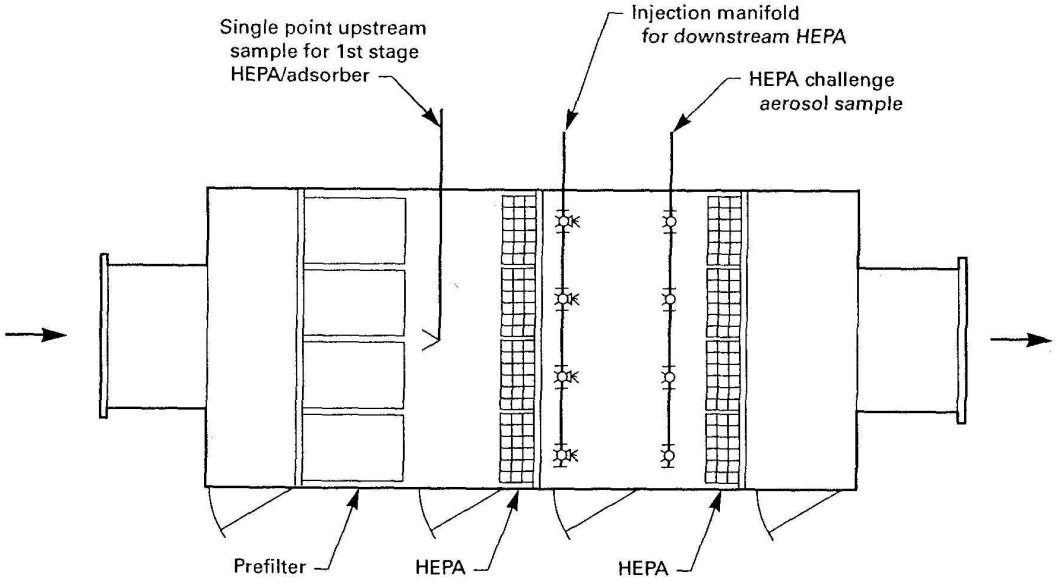
GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample port may be located in outlet duct.

Figure 4.31 – Common configurations requiring test manifolds (Plan A)



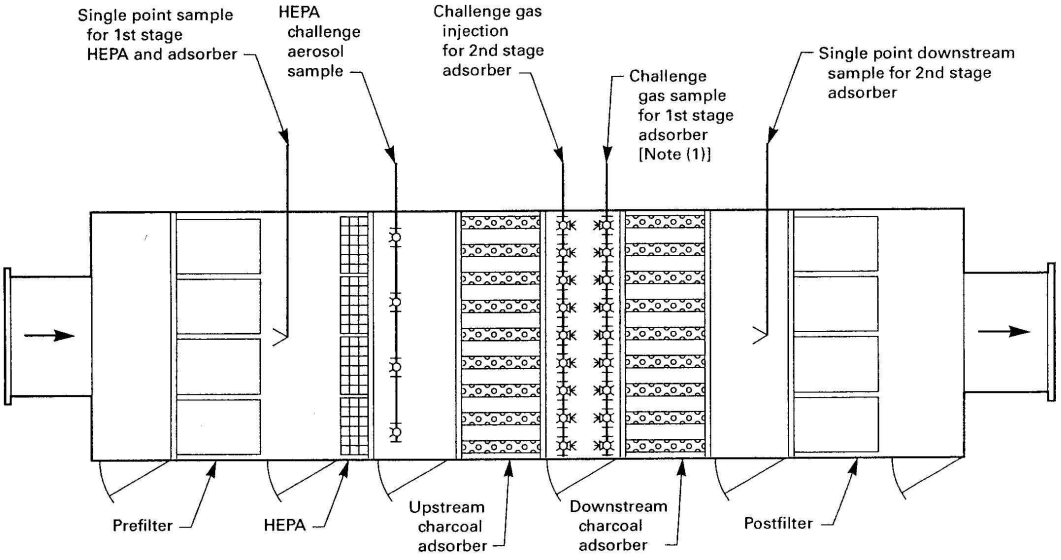
GENERAL NOTES:
(a) If an inlet duct is provided, the challenge aerosol/gas injection can be located in the inlet duct.
(b) If an outlet duct is provided, the downstream sample can be located in the outlet duct.

Figure 4.32– Common configurations requiring test manifolds (Plan B)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

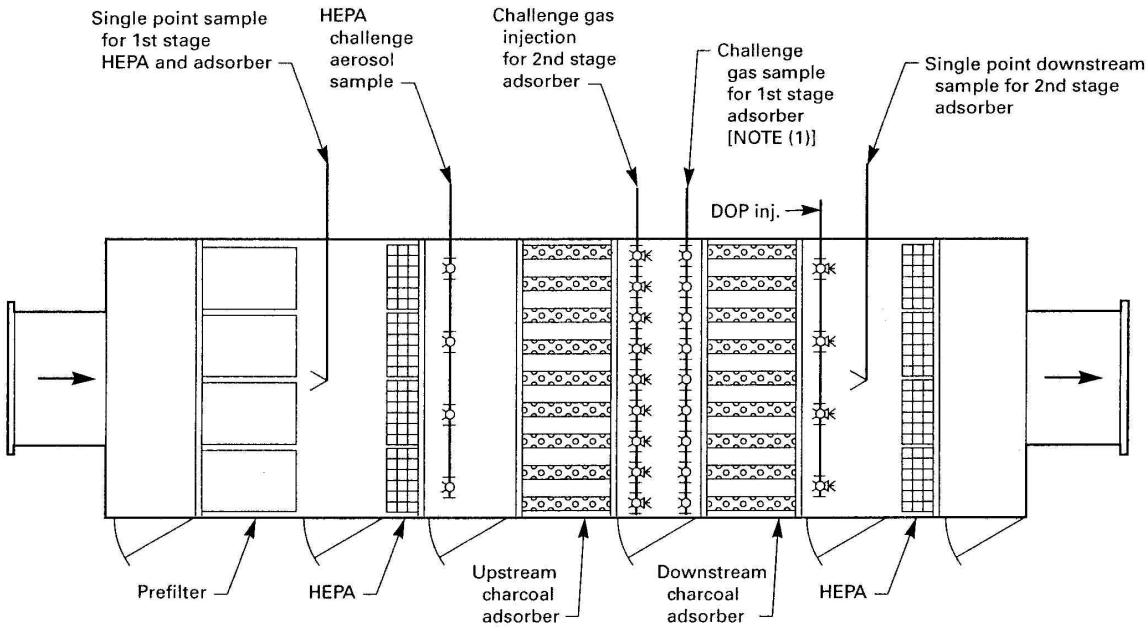
Figure 4.33 – Common configurations requiring test manifolds (Plan C)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

NOTE:
(1) 1st stage challenge gas sample point can be used for 2nd stage upstream sample in lieu of single point sample.

Figure 4.34 – Common configurations requirng test manifolds (Plan D)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

NOTE:
(1) 1st stage challenge gas sample point can be used for 2nd stage upstream sample in lieu of single point sample.

Figure 4.35 – Common configurations requiring test manifolds (Plan E)

The procedures required for construction and operational maintenance must be considered in the early planning stages. Adequate clearances for access must be maintained at turning points and between the bank and the nearest obstruction. Passageways both between the banks and between the banks and the housing wall must be wide enough for welders to operate effectively and for workmen, dressed in bulky clothing, to get in to change filters (see **FIGURES 36 and 37**). Both welders and workmen will have to kneel or stoop to get to the bottom tier. A 95th-percentile man in a kneeling position requires a minimum clearance of 36 in. from the face of the filters to the nearest obstruction, excluding withdrawal space for the filter unit itself. A minimum clearance of 40 in. is therefore recommended between the face of one bank and the nearest obstruction.

4.4.14 STEEL HOUSINGS

Design practices used for conventional air conditioning and ventilation system ductwork and equipment casings are not adequate for high-reliability, high-efficiency contaminated-exhaust and air cleanup systems. Experience has shown that, under system upset and shutdown conditions, housing leaks can result in the escape of contamination to clean areas. Even with fans operating, reverse leakage of particles from the low-pressure side of a system (i.e., the interior of the housing or duct) to the high-pressure side (i.e., the occupied area of the building) can sometimes occur because of dynamic and aspiration effects. Out-leakage may also occur when the system is shut down. Filter housings for contaminated exhaust service must be able to withstand negative pressures without damage or permanent deformation at least up to fan cutoff, which may be equal to 20 in.wg in many systems. A pressure differential of 2 in.wg between the inside and outside of a housing produces a load of more than 1,000 lb over every 10 ft^2 of the housing wall. If the filters are operated to economical pressure drops, the housing may have to withstand ten or

more times this load without appreciable deflection. Pulsation and vibration may aggravate the condition. In addition, the housing should be able to withstand design shock loads without damage.

The references cited in Section 4 for the design, fabrication, and welding of mounting frames are also applicable to steel housings. Housings should be of all-welded construction, with bolted flange or welded inlet and outlet connections to the ducts and fans. **TABLE 4.3** gives minimum sheet-metal thicknesses for sheet steel housings, and **TABLE 4.4** gives minimum moments of inertia for steel reinforcing members. Sheet-metal thicknesses in TABLE 4.4 are based on a maximum deflection of 1/4-in./lin.ft at a pressure differential between the interior of the housing and atmosphere equivalent to 1.5 times the maximum pressure at fan cutoff. The moments of inertia for reinforcing members listed in TABLE 4.4 were selected to avoid exceeding the allowable stress of the steel. Members up to 20 in. long were considered to be uniformly loaded beams with fixed ends, whereas members longer than 20 in. were considered to be uniformly loaded beams with simply supported ends. The sheet-metal thicknesses in TABLE 4.3 are given in U.S. gage numbers for sheet and fractional inches for plate.

Figure 4.36 – HEPA filter mounted on up stream side of mounting frame

Figure 4.37 – Blanking plate being installed on down stream side of mounting frame

Table 4.3 – Minimum Sheet-Metal Thicknessess[a] for Welded Steel[b] Filter Housings under Negative Pressure

Dimensions of largest unsupported panel (in.)		Thickness (U.S. gage for sheet, fractional in. for plate) for negative pressure (relative to outside)					
Long side[d]	Short side	4 in.wg	8 in.wg	12 in.wg	20 in.wg	1 psi	2 psi
54 (2)	12	18	18	14	16	14	11
	24	18	14	11	12	8	1/4
	36	16	12	8	11	1/4	3/8
	48	14	12	6	8	1/4	3/8
80 (3)	12	18	16	14	16	14	11
	24	18	14	11	12	8	1/4
	36	16	12	6	11	1/4	3/8
	48	14	12	6	8	1/4	3/8
106 (4)	12	18	16	16	14	14	11
	24	18	14	12	11	8	1/4
	36	16	12	8	6	1/4	3/8
	48	16	10	6	1/4	3/8	

[a]Based on flat plate edges held but not fixed (F.J. Roark, *Formulas for Stress and Strain*),[19] and maximum deflection of 0.25 in./ft between reinforcements.
[b]30,000 to 38,000 psi yield strength.
[c]Metal thickness less than No. 18 U.S. gage are not recommended because of welding problems.
[d]Length based on 2-in. spacing between 24- by 24-in. filter units; the numbers within parentheses denote number of filter units. The metal thicknesses are adequate for panel lengths within ±10 in. of the length shown.

Note: This table is intended to provide information only. The designer is responsible for verifying this information.